TITLE: An Evaluation of Input Devices and Menu Systems for Remote Workstations

An Evaluation of Input Devices and Menu Systems for Remote Workstations

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SUMMARY

It is likely that the future air fleet will include uninhabited air vehicles (UAVs) that can be controlled by an operator in a remote location. Such a system will require the operator to experience the same view as the onboard camera to maintain control and keep track of the uninhabited vehicle. It should be borne in mind that uninhabited vehicles are not likely to be continuously operational but deployed only when necessary. The interface must therefore be intuitive, as long periods of time could elapse between missions. The training needs of the operator should therefore be less intensive than those currently necessary for the manned aircraft fleet. As missions may employ a semi-autonomous mode of operation, there is a requirement for transparency between the system and the operator inputs. This paper reports an investigation of the utility of three Windows-driven menu systems and four input devices. Performance with a touchscreen, touchpad, keyboard and mouse was compared on a waypoint re-routing task. It was anticipated that the innovative touchscreen would enhance performance when compared to the more conventional input methods of keyboard or mouse. The literature suggested that performance with the touchpad would not be optimal. The experiment was run in three phases, each phase using a different menu structure. Pull-down menus, pop-up menus and horizontal menus were included. The results show that in this type of scenario, less emphasis should be placed on the menu system to be used than the input device, although pop-up menus may be less desirable. The mouse and the touchscreen provide performance advantages in comparison to the keyboard and the touchpad.

1. INTRODUCTION

It is likely that the future air fleet will include uninhabited vehicles that can be controlled by an operator in a remote location. Such a system will require the operator to experience the same view as the onboard camera to maintain control and keep track of the vehicle. It should be borne in mind that uninhabited vehicles are not likely to be continuously operational but deployed only when necessary. The interface must therefore be intuitive as long periods of time could elapse between missions. The training needs of the operator should therefore be less intensive than those currently necessary for the manned aircraft fleet. As missions may employ a semi-autonomous mode of operation, there is a requirement for transparency between the system and the operator inputs. This places the emphasis for control on the design of an intuitively usable workstation. Generally there are three ways to input information: cursor commands (mouse or touchpad), point commands (light pen or finger) and direct command methods that use keyboard input or voice input for sequence control (Gibbons, 1992). This paper will investigate the utility of three Windows-driven menu systems and four input devices to aid control of a remote vehicle. Performance with pull-down, pop-up and horizontal menu systems, and keyboard, mouse, touchpad and touchscreen input devices, will be considered.

1.1 Menus

Menus are an effective method of interface design and can make interface operation easier for users. They offer choices that have only to be recognised by the user, rather than requiring the user to learn and recall complex syntax and command strings, thus using less cognitive resources and facilitating concentration on the primary task (Schneiderman, 1998). Menu systems can therefore be particularly useful when intermittent use of a system is likely; this lends itself to the control of UAVs. In addition, they enable the user to see the range of alternatives available (Newman and Sproull, 1984). Menus also lead to fewer errors than command-based interfaces, because they allow only certain actions to be performed (Benbasat and Todd, 1993). Once a user has indicated his menu choice via the input device he will receive feedback indicating what has happened, making a menu interface appealing to users as well as easy to use. However, menu systems reduce user freedom as choices are dictated by the system (Booth, 1992). There are many different types of menu, but the ideal menu for use within a particular interface emerges only as a result of careful interface design.

Pull-down menus have top-level headings permanently displayed on the menu bar at the top of the screen/window. The user displays the menu by "pulling down" or selecting an item (BS ISO, 1997). Further

Paper presented at the RTO SCI Symposium on "Warfare Automation: Procedures and Techniques for Unmanned Vehicles", held in Ankara, Turkey, 26-28 April 1999 and published in RTO MP-44.

selections can then be made from the displayed menu. Although the top level choices are always displayed, the menus can obscure screen space when they drop down.

Pop-up menus do not have a permanent menu bar displayed. A click on the input device "pops up" the menu wherever the cursor happens to be at the time (BS ISO, 1997). The advantages are fewer cursor (and therefore hand) movements as the user does not have to keep moving the cursor to the top/bottom of the screen to make a selection (Newman and Sproull, 1984). In addition, this format saves screen space. However, as the menu (and associated sub-menus) may appear in different places there is no chance for the user to learn the spatial location of frequently used menu items. When information is in a constant location, users acquire expectations about where items will appear, and this gradually improves response times (Norman, 1991).

Horizontal menus are the older type of menu commonly found on DOS-based systems. One top-level menu item and its associated sub-choices are displayed on a status bar usually at the bottom of the display. To change the menu the user selects the top level to the left of the display bar and all the viewable options change. However, only one mode can be presented at any time, requiring the operator to toggle between top-level menus as appropriate. One further limitation exists: there will be a limit to the number of menu items that can be displayed (Newman and Sproull, 1984). However, the advantage is that these menus do not obscure the screen.

1.2 Input Devices

It has been argued that input devices such as touchscreens, mice, joysticks and trackballs have an advantage over the keyboard because they allow manipulation of the screen content in a direct manner (Han, Jorna, Miller and Tan, 1990). However, Gould, Green, Boies, Meluson and Rasamny (1990) found that data entry could be faster with the keyboard than other devices if aided automatic string completion was used on a task. Hence, it appears that the nature and conditions of the task can determine the most desirable device. For example, a mobile ground-station for a UAV may have different requirements from a fixed-base command and control station headquarters. The keyboard is, however, often regarded as the most suitable device for data entry (Gould et al, 1990).

The mouse is considered to be quick and accurate, especially on smaller targets (Sears and Schneiderman, 1991). However, it does have some disadvantages. First, it consumes desk space, as does its lead, which can be distracting or become entangled (Brown, 1988). Secondly, it needs some practice to acquire the skill. For very long motions it also requires the whole device to be picked up and repositioned. Finally, it is a moving part, which makes it liable to "getting lost" in public applications, and it is not as rugged as a touchscreen for this type of application (Schneiderman, 1998). Brown (1988) suggests that in mobile environments a mouse may not be the most suitable input device. Once again in a mobile UAV unit, these may be important considerations. However, there are some advantages in the use of a mouse. During operation the hand does not obscure the screen, it is comfortable to use and may be the preferred input device for click and drag manoeuvres. It is now the industry standard and most potential users would already be familiar with it.

In a review, Schneiderman (1998) concludes that the major advantage of the touch tablet is that the hand does not obscure the screen as it would in touchscreen use and that it may be more comfortable for the user. However, it does take up desk space. In addition Han et al (1990) found that performance is very slow with the tablet and users do not like it.

Touchscreens are considered to be a natural pointing device (Sears, 1991). They are reported to be simple to operate and easy to learn, with rapid performance and potentially low error rates (Sears and Schneiderman, 1991). It has been reported that the early problems with precision have now been resolved by advances in technology (Schneiderman, 1998). However, touchscreens are not ideal for typing large amounts of data. In his review, Schneiderman (1998) points out that touchscreens are very durable as they have no moving parts, making them ideal for military use. Gould et al (1990) state that touchscreens have "behavioural advantages". Less space is required for their use and they are also a very flexible interface, capable of presenting various displays to suit the task, such as icons, windows and keyboards. A potential problem with touchscreens, however, is the possibility of touch biases. Touch biases refer to differences between the intended and actual locations selected. This could also account for some of the reduced accuracy sometimes seen with a touchscreen.

Karat et al (1986) state that improved performance seen on touchscreens may be due to the fact that mouse and keyboard operation involves more cognitive processing, whereas pointing is a highly automated skill for humans. Schneiderman (1998) points out that mouse use requires not only more cognitive processing, but also hand-eye co-ordination when moving the cursor. Sears and Schneiderman (1991) therefore conclude that the touchscreen is as fast, or faster than, the mouse except for very small targets. Sears (1991) also suggests that the touchscreen allows "more natural selections" (pp 265). This could be relevant for UAVs, as the operator may be under high workload, and the lower the cognitive processing required the better.

In general the most appropriate input device seems to depend on the type and demands of the task, the operational environment and the end-users (Schneiderman, 1998; Fernandez et al, 1988; Sears, 1991). However, it was anticipated that an innovative touchscreen device would enhance performance on a waypoint re-routing task when compared to the more conventional input methods of keyboard or mouse.

2. METHOD

2.1 Participants

Thirty-six participants (26 male, 10 female) were selected from an opportunity sample of Defence Evaluation and Research Agency (DERA) staff. They were aged 20 to 34 with a mean age of 25. They reported normal or corrected-to-normal visual acuity. Of the 36 participants, 4 were left-handed and 32 right-handed.

2.2 Materials

A demonstration trial, a practice trial and two main trials were generated using a Silicon Graphics Onyx[2] computer, presented on a monitor with a 47.5 cm x 30 cm visual screen. Each trial consisted of a static map display with a pre-determined set of waypoints that indicated the planned route a UAV was to follow. The demonstration trial and the practice trial consisted of five tasks: pre-flight re-routing; launch of vehicle; in-flight re-routing due to a surface-to-air-missile (SAM) zone; acknowledgement and identification of a target; and, finally, recovery of the vehicle. For each of the main trials there were eight tasks, the five tasks as before and an additional pre-flight re-route, in-flight re-route and target acknowledgement and identification.

The task required participants to carry out actions based on events as they occurred. The events were signified by audio messages, generated by a Silicon Graphics Sound Editor software package. New waypoints, targets and launch and recovery points were also indicated by flashing letters or symbols (as appropriate) on the screen.

Participants were asked to carry out actions using one of four input devices. The touch tablet used was a Cirque "Smart Cat" touchpad and will therefore be referred to as the touchpad within this paper. Three different menu types were used to allow the participants to interact with the display.

2.3 Design

A two-way mixed measures design was used. The independent measures were input device (four levels) and menu type (three variables). Each participant was presented with each of the input devices: keyboard, mouse, touchpad and touchscreen. However, participants were exposed to only one of the menu types: pull-down, pop-up or horizontal.

The dependent measures were error rate (calculated as the number of times a task was not correctly completed), response time (the time taken for participants to press a response key) and total task time (calculated as the overall time taken to complete a trial). For the purposes of reporting the data the main trials were broken down into five tasks. Replicated tasks were simply meaned. Subjective measures were also recorded in pre- and post-experimental questionnaires.

Each participant was presented with only one of the main trials (1 or 2) for each input device. Main trial 2 represented a reversal of events and a 180^0 rotation of main trial 1. To reduce familiarity with the route, for all participants the first input device presented was shown with main trial 1, the second with main trial 2, the third with main trial 1 and the fourth with main trial 2.

2.4 Procedure

To prevent learning and/or order effects, the order of use of input devices was balanced using a replicated 4 x 4 design. Twelve participants completed each menu system. Upon arrival participants were presented with written instructions for completion of the task. They were asked to complete a demographic questionnaire that included questions regarding their familiarity with and preference for the four input devices and their familiarity with the appropriate menu system. They were then asked to sign consent forms. A practical demonstration was given by the experimenter, on how to complete the task, with emphasis on the menu system to be used. Following this, participants received a further set of instructions outlining the first input device to be used. Participants then completed one practice trial and one main trial. Before each of the subsequent input devices was used, device-specific instructions were presented, but no further demonstrations were given.

During the practice trials, data were not recorded. In the main trials, response times were recorded in seconds to four decimal places. Following completion of the experiment, participants completed a post-experimental questionnaire that asked them to rank again their preferences for the input devices. Participants were then debriefed.

3. RESULTS

3.1 Objective Measures

As explained in the design section of the method, each participant was presented with one of the two main trials for each input device. There is evidence of training between the two trial runs, whereby run 1 produced significantly longer response times than run 2. However, this does not interact overall with the menu systems and input devices and will therefore not be reported further.

3.1.1 Error Rates

Very few errors were made in the trials (0.4%). An error analysis was therefore not conducted.

3.1.2 Response Times (RTs)

All data required a log transform. Missing values were estimated. Differences between input devices and menu systems were analysed using the Newman-Keuls range test. Outliers were removed before analysis (0.6%). All means presented are back-transformed. Trials in which participants had responded incorrectly were not included in the analyses. A two-way mixed Analysis of Variance (ANOVA) was performed on the factors Menu and Input Device.

3.1.2.1 Pre-flight re-routing

A significant main effect of Input Device ($F(3, 99) = 45.62$, $p<0.001$) was found. Post hoc analyses for the main effect of Input Device showed that the mouse and touchscreen produced significantly faster response times than the touchpad ($p<0.001$) and the keyboard ($p<0.001$). Mean RT scores for Input Device and Menu are shown in Table 1.

Input Device	Pull-down	Pop-up	Horizontal	Mean
Keyboard	21.31	21.12	18.07	**20.17**
Mouse	12.59	14.84	13.40	**13.61**
Touchpad	20.22	22.61	20.34	**21.05**
Touchscreen	13.43	12.40	13.32	**13.05**
Mean	**16.89**	**17.74**	**16.28**	

Table 1: Mean RT for Input Device and Menu for Pre-flight Re-routing (in seconds)

3.1.2.2 Launch of the vehicle

Significant main effects of Menu ($F(2, 125) = 17.81$, $p<0.001$) and Input Device ($F(3, 125) = 6.26$, $p<0.01$) were found. Post hoc analyses for the main effect of Menu showed that the horizontal and pull-down menus produced significantly faster response times than the pop-up menu ($p<0.01$). Post hoc analyses for the main effect of Input Device showed that the touchscreen and mouse produced significantly faster response times than the keyboard ($p<0.001$) and the touchpad ($p<0.001$). Mean RT scores for Input Device and Menu are shown in Table 2.

Input Device	Pull-down	Pop-up	Horizontal	Mean
Keyboard	5.10	5.99	4.31	**5.14**
Mouse	3.26	4.49	3.88	**3.88**
Touchpad	4.76	6.19	4.96	**5.30**
Touchscreen	3.68	3.94	3.84	**3.82**
Mean	**4.20**	**5.15**	**4.25**	

Table 2: Mean RT for Input Device and Menu for the Launch of the Vehicle (in seconds)

3.1.2.3 In-flight re-routing

Significant main effects of Menu ($F(2, 33) = 3.65$, $p<0.05$) and Input Device ($F(3, 99) = 34.63$, $p<0.001$) were found. Post hoc analyses for the main effect of Menu showed that the pull-down menu produced significantly faster response times than the pop-up ($p<0.05$) and horizontal menus ($p<0.05$). Post hoc analyses for the main effect of Input Device showed that the touchscreen and mouse produced significantly faster response times than the keyboard ($p<0.001$) and the touchpad ($p<0.001$). Mean RT scores for Input Device and Menu are shown in Table 3.

Input Device	Pull-down	Pop-up	Horizontal	Mean
Keyboard	17.04	17.41	17.33	**17.26**
Mouse	10.86	13.35	13.51	**12.57**
Touchpad	16.91	18.28	20.00	**18.40**
Touchscreen	11.37	14.12	14.67	**13.39**
Mean	**14.05**	**15.79**	**16.38**	

Table 3: Mean RT for Input Device and Menu for In-flight Re-routing (in seconds)

3.1.2.4 Acknowledgement and identification of a target

Significant main effects of Menu ($F(2, 33) = 5.98$, $p<0.01$) and Input Device ($F(3, 99) = 54.60$, $p<0.001$) were found. There was also a significant interaction between Input Device and Menu ($F(6, 99) = 2.85$, $p<0.05$). Post hoc analyses for the main effect of Menu showed that the pull-down and horizontal menus produced significantly faster response times than the pop-up menu ($p<0.01$). Post hoc analyses for the main effect of Input Device showed that the touchpad ($p<0.01$), touchscreen ($p<0.001$) and the mouse ($p<0.001$) produced significantly faster response times than the keyboard. The touchscreen and the mouse also produced significantly faster response times than the touchpad ($p<0.001$). In addition, the mouse produced significantly faster response times than the touchscreen ($p<0.01$).

Post hoc analyses for the interaction between Input Device and Menu showed that for the pull-down menu the touchpad ($p<0.05$), the touchscreen ($p<0.001$) and the mouse ($p<0.001$) produced significantly faster responses than the keyboard. The touchscreen and the mouse also produced significantly faster response times than the touchpad ($p<0.001$). For the pop-up menu the touchscreen and the mouse produced significantly faster response times than the keyboard ($p<0.001$) and the touchpad ($p<0.001$). For the horizontal menu the touchscreen ($p<0.05$) and the mouse ($p<0.001$) produced significantly faster response times than the keyboard. The mouse also produced significantly faster response times than the touchpad and the touchscreen ($p<0.001$). For the keyboard the horizontal menu produced significantly faster response times than the pop-up menu ($p<0.05$). For the mouse and touchpad the pull-down and horizontal menus produced significantly faster response times than the pop-up menu ($p<0.01$). Mean RT scores for Input Device and Menu are shown in Figure 1.

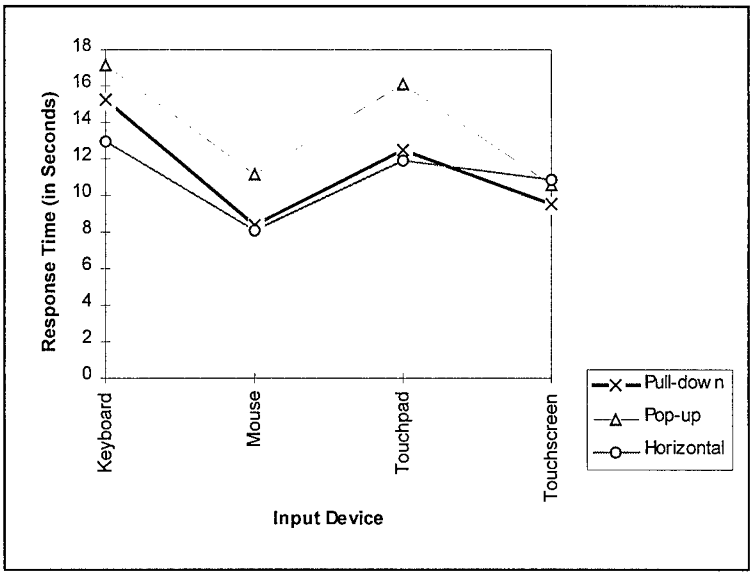

Figure 1: Graph showing RTs for Input Device and Menu for the Acknowledgement and Identification of a Target (in seconds)

3.1.2.5 Recovery of the vehicle

Significant main effects of Menu (F (2, 33) = 3.80, $p<0.05$) and Input Device (F (3, 99) = 7.48, $p<0.001$) were found. Post hoc analyses did not show the source of the significant main effect of Menu. However, it can be seen in Table 4 that there was a trend for the pull-down and horizontal menus to produce faster response times than the pop-up menu. Post hoc analyses for the main effect of Input Device showed that the touchscreen ($p<0.05$) and the mouse ($p<0.001$) produced significantly faster response times than the touchpad. The mouse also produced significantly faster response times than the keyboard ($p<0.001$). Mean RT scores for Input Device and Menu are shown in Table 4.

Input Device	Pull-down	Pop-up	Horizontal	Mean
Keyboard	3.32	7.64	2.91	**4.62**
Mouse	2.38	4.79	2.64	**3.27**
Touchpad	4.11	7.69	4.28	**5.36**
Touchscreen	3.44	4.38	3.71	**3.85**
Mean	**3.31**	**6.12**	**3.39**	

Table 4: Mean RT for Input Device and Menu for Recovery of the Vehicle (in seconds)

3.1.2.6 Total task time

A significant main effect of Input Device (F (3, 129) = 43.84, $p<0.001$) was found. Post hoc analyses showed that the touchscreen and the mouse produced significantly faster response times than the keyboard ($p<0.001$) and the touchpad ($p<0.001$). Figure 2 illustrates the total task time.

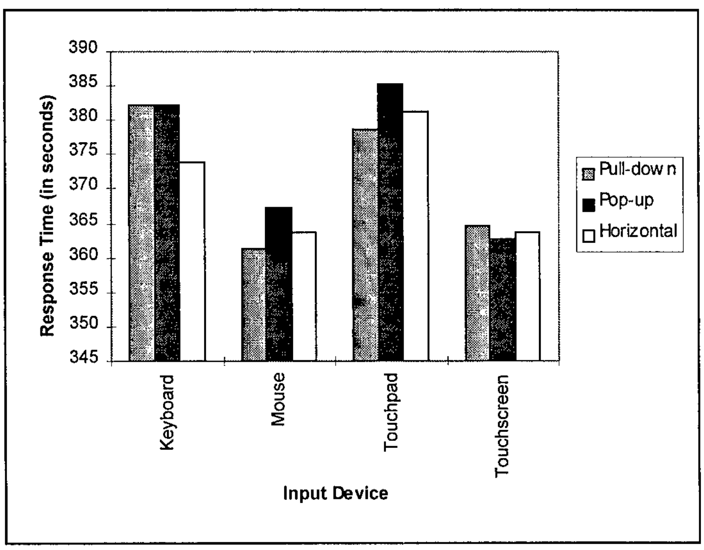

Figure 2: Mean RT for Input Device and Menu for Total Task Time (in seconds)

3.2 Subjective Measures

3.2.1 Pre-experimental familiarity with input devices

Participants were asked to rate how familiar they were with each of the four input devices to be used, before participating in the trial. It can be seen in Table 5 that the participants were more familiar with the use of the keyboard and the mouse than the touchpad and the touchscreen. Mean ratings for familiarity with the input devices are shown in Table 5.

Input Device	Never Used	Unfamiliar	Familiar	Often Used
Keyboard	0	0	2	34
Mouse	0	0	2	34
Touchpad	8	12	15	1
Touchscreen	4	12	19	1

Table 5: Familiarity with the Input Devices: Pre-experimental Mean Ratings

3.2.2 Pre-experimental preferences for input devices

Participants were also asked to rank order their preferences for the four input devices before participating in the trial. It can be seen in Table 6 that the participants ranked the keyboard and mouse highly, in line with their familiarity of use. The mouse was the preferred input device. The ranks shown represent 35 of the 36 participants' data. One participant's data were removed as the post-experimental questionnaire was incorrectly completed. Hence it could not be used for comparison. Mean ranks for the input devices are shown in Table 6.

Input Device	1st	2nd	3rd	4th
Keyboard	11	12	10	2
Mouse	16	16	3	0
Touchpad	1	2	3	29
Touchscreen	7	5	19	4

Table 6: Pre-experimental Mean Ranks for the Input Devices

3.2.3 Pre-experimental familiarity for menu systems

Participants were also asked about their familiarity with the type of menu system they were about to use in the trial. As only one third of participants were presented with each menu type, there were only 12 participants in each group. It can be seen in Table 7 that participants were more familiar with the pull-down menu and least familiar with horizontal menu systems. Mean ratings for familiarity with the input devices are shown in Table 7.

Menu Type	Never Used	Unfamiliar	Familiar	Often Used
Pull-down	0	0	0	12
Pop-up	0	1	1	10
Horizontal	0	2	3	7

Table 7: Familiarity with the Input Devices: Pre-experimental Mean Ratings

3.2.4 Post-experimental preferences for input devices

Participants were asked again to rank order their preferences for the four input devices on completion of the trial. It can be seen in Table 8 that the participants ranked the touchscreen as the preferred device. It is interesting to note that the keyboard was ranked third overall. The ranks shown represent 35 of the 36 participants' data as one participant gave equal ranks to devices, despite the instructions given for completion. This participant's data were therefore removed. Mean ranks for the input devices are shown in Table 8.

Input Device	1st	2nd	3rd	4th
Keyboard	0	3	18	14
Mouse	8	24	3	0
Touchpad	3	2	12	18
Touchscreen	24	6	2	3

Table 8: Post-experimental Mean Ranks for the Input Devices

4. DISCUSSION

For total task time, pre-flight re-routing, launch of the vehicle, in-flight re-routing and recovery of the vehicle, the results show that the mouse and the touchscreen produced performance advantages in comparison to the keyboard and the touchpad, on a waypoint re-routing task. However, for target acknowledgement and identification, the mouse gave faster response times than the touchscreen. The touchscreen may not have provided performance advantages over the mouse because it did not prove to be 100% reliable over the trial. There were some instances when the touchscreen did not respond at the initial press. However, this was not reported as a problem most of the time and may sometimes have been due to user style. For the acknowledgement and identification of a target, the touchpad provided performance benefits in comparison to the keyboard. For the recovery of the vehicle, the mouse also gave performance advantages over the keyboard.

In designing the experiment it was difficult to decide how similar to keep the use of each menu and input device. The aim was to allow the advantages of each menu and input device to be maintained within a similar design structure to enable fair comparisons to be made. However, with the keyboard this was particularly

difficult as the task involved direct manipulation. This type of task is inherently unsuited to the use of a keyboard. To permit the input of waypoint data when using the keyboard, it was necessary to use the tab keys for some of the menu selections, but the cursor keys for others. Participants were also required to press the space bar rather than the return key to select menu options and acknowledge dialogue boxes. In addition, keyboard inputs for the pull-down and pop-up menus required other buttons to be pressed to display menu options. For example, with the pop-up menu, the control button had to be pressed. This may have contributed to the performance advantage shown by the horizontal menu in comparison to the pop-up menu, when using the keyboard. It is more difficult to remember a particular key than simply to make a selection with a mouse. More familiarity may be required with the keyboard to increase the speed of use. Effective use of short-cut keys would help, but these could be forgotten due to intermittent use.

It is likely that the poor performance of the touchpad could be attributed partly to the speed/distance ratio of the scrolling mechanism when movements of large distances were required. Several repetitive movements were required to scroll across the screen from one side to the other. A further problem participants experienced with the touchpad was deselecting items by accidentally tapping the pad when moving the cursor to a menu option. Another possible explanation is the unfamiliarity of the participants with this device. However, this could not be the only explanation, as participants were also unfamiliar with the use of touchscreens.

It is interesting to note that the results do not show a significant performance benefit overall (total task time) for any of the three menu systems used. However, for the launch of the vehicle and the acknowledgement and identification of a target, the results show that the pull-down and horizontal menus produced faster response times than the pop-up menu. It is not surprising that the pop-up menu required extra time to respond, as an additional button press is required to enable the top-level menus to be observed before a selection can take place. Some participants also found that it was inconvenient to have the display "pop-up" near the cursor, blocking part of the display. In addition, further action would need to have been taken to move the position of the menu on the screen to a more suitable location. For in-flight re-routing, however, the results showed that the pull-down menu gave faster response times than both the pop-up and horizontal menus.

The interaction between Input Device and Menu for acknowledgement and identification of a target showed that, for the pull-down and pop-up menus, the touchscreen and mouse gave similar performance advantages. For the horizontal menu the mouse performed the fastest. One possible explanation is that a smaller movement was needed with the mouse to identify the target than for the touchscreen, as the finger was usually removed from the screen between selections. As the buttons in this horizontal menu were adjacent, more effort would be required in using the touchscreen than the mouse. It is interesting to note that, for the keyboard, the horizontal menu provided performance advantages over the pop-up menu. However, for the mouse and touchpad the horizontal and pull-down menus gave similar performance levels above those for the pop-up menu. It should be noted that mode errors occurred more frequently with the horizontal menu. Such errors typically occurred between the pre-flight and the in-flight re-routing on the second re-route task. Once the target had been identified a change of mode switched to mission planning. As the dialogue boxes to enter the waypoint information were similar to those in the in-flight mode some participants did not realise that they were not in navigation mode. It appears that performance with the touchscreen is affected less by menu type than the remaining input devices (refer to Figure 2).

The subjective data show that one third of the participants were unfamiliar with the use of a touchscreen and a touchpad, whilst some participants had never used such devices before. The majority of participants were familiar with the menu system to which they were exposed, but they were less familiar with the horizontal menus than the pull-down and pop-up menus. This is not unexpected given the use in industry of Microsoft Windows-based products. It would have been interesting to ask the participants for a subjective preference for menu type. However, this was not possible as participants were exposed to only one menu system and did not know about the testing of others until they had completed the experiment.

A comparison of the pre-experimental and post-experimental rank orders for participants' preferences for the input devices showed an interesting difference. Before the trial began, participants ranked the mouse as the preferred input device and the keyboard second. However, on completion of the experiment, the touchscreen was ranked as the preferred input device and the mouse second. It is possible that the difference in pre- and post-experimental rankings could be partly due to the specific scenario being used to rank the devices post-experimentally. Nevertheless, it is useful to note that the majority of the participants preferred the touchscreen rather than the mouse for this task, and that the keyboard was not placed high in the ranks.

Comments made during the trials by the participants were recorded for later discussion. One comment referred to the speed at which the trial was run, explaining that it was easy to get distracted because the trial was too slow. However, the task had to be run at a slower pace than envisaged to ensure the feasibility of participants being able to complete the first trial when the task, input devices and menu system would be unfamiliar to them. In a real-world scenario, a similar task would require a monitoring capability, so the distraction element may have actually made the task more realistic. It was also suggested that the mouse cursor should be enlarged and that an accelerated mouse

may be more appropriate for the task. Other input devices, such as a trackball, or the use of direct voice input, could have been considered. A further suggestion was that some buttons could be permanently available on the screen for touchscreen use; this would reduce the number of menu options required on the display. It was recognised by some participants that actions were required only when a new waypoint marker had been reached. Unfortunately this was a consequence of the way the program was written; event markers were required to prompt activity.

In conclusion, this research has illustrated the significance that an input device can have for operator performance on a waypoint re-routing task. It appears that in this type of scenario less emphasis should be placed on the menu system to be utilised, although pop-up menus may be less desirable. The focus should therefore be placed on the device for interaction. Future workstation design should therefore consider the use of a touchscreen or mouse for control of remotely-operated vehicles. A touchscreen may be preferable as its performance seems more stable across menu systems and was reported as the preferred choice by operators in this experiment. Future research will investigate the utility of the mouse and the touchscreen further.

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This work was funded by Technology Group 5 (Human Sciences and Synthetic Environments) of the UK Ministry of Defence's Corporate Research Programme.